

Impacts of Heterogeneous and Clumped Vegetation Structure on Land Surface Energy Balance and Snowmelt in Cold Regions

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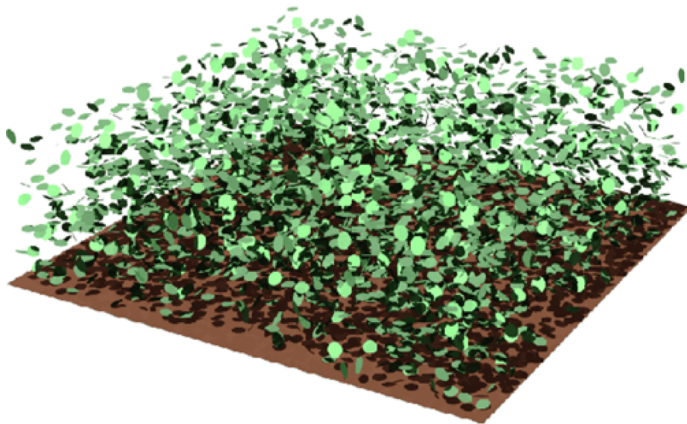
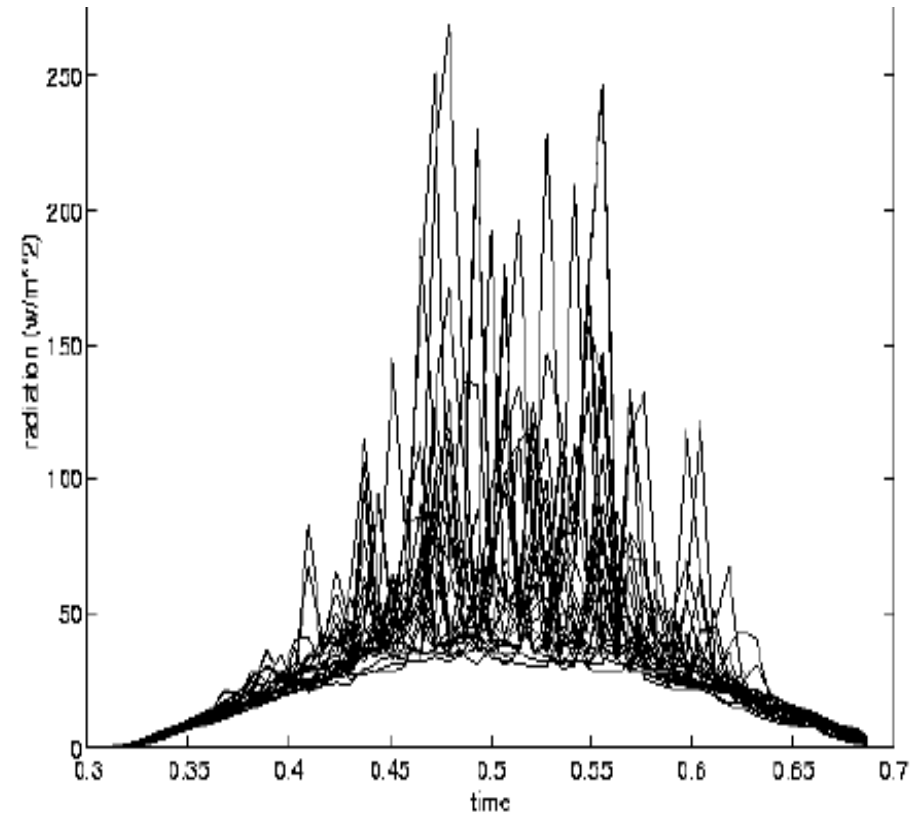
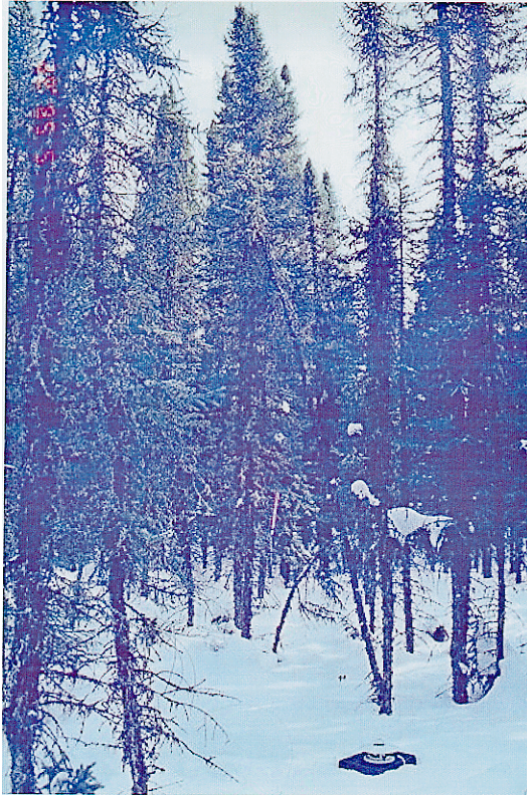
SnowEx-ABOVE planning Meeting

August 13, 2019

Outline

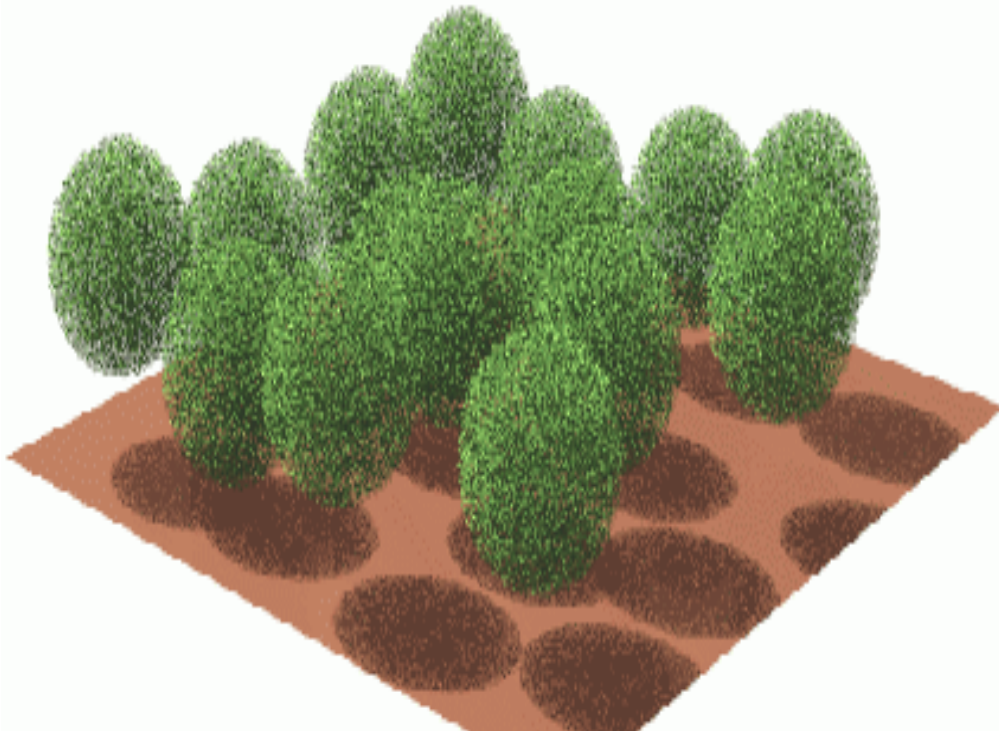
- How does the heterogeneous and clumped vegetation structure affects
 - Surface albedo
 - Snow Albedo Feedback Issue
 - SWE and snowmelt
 - How does vegetation structure impact SWE and snowmelt?

Solar Radiation Under an Old Jack Pine Forest



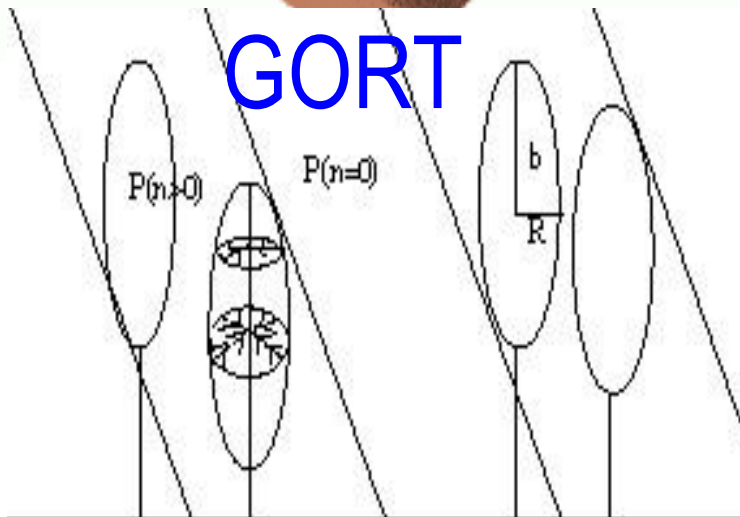
Issue with the Big Leaf Model

Geometric Optical and Radiative Transfer Model (GORT)



Geometric Optics (GO) theory:

- Gap Probabilities
- areal proportions of sunlit and shaded scenes

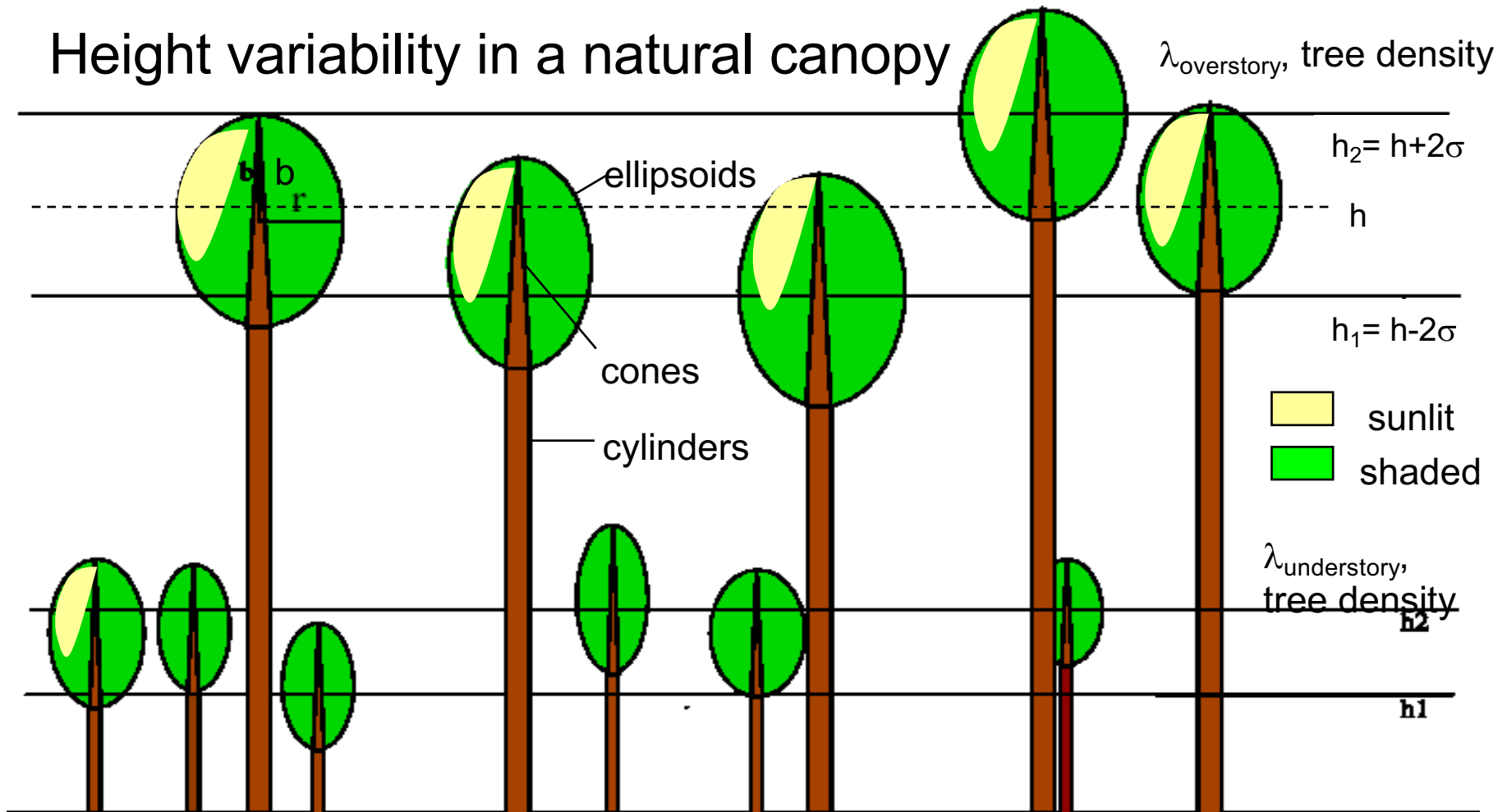


Radiative Transfer (RT) theory:

- Multiple Scattering

Li et al (1995) and Ni et al, 1997

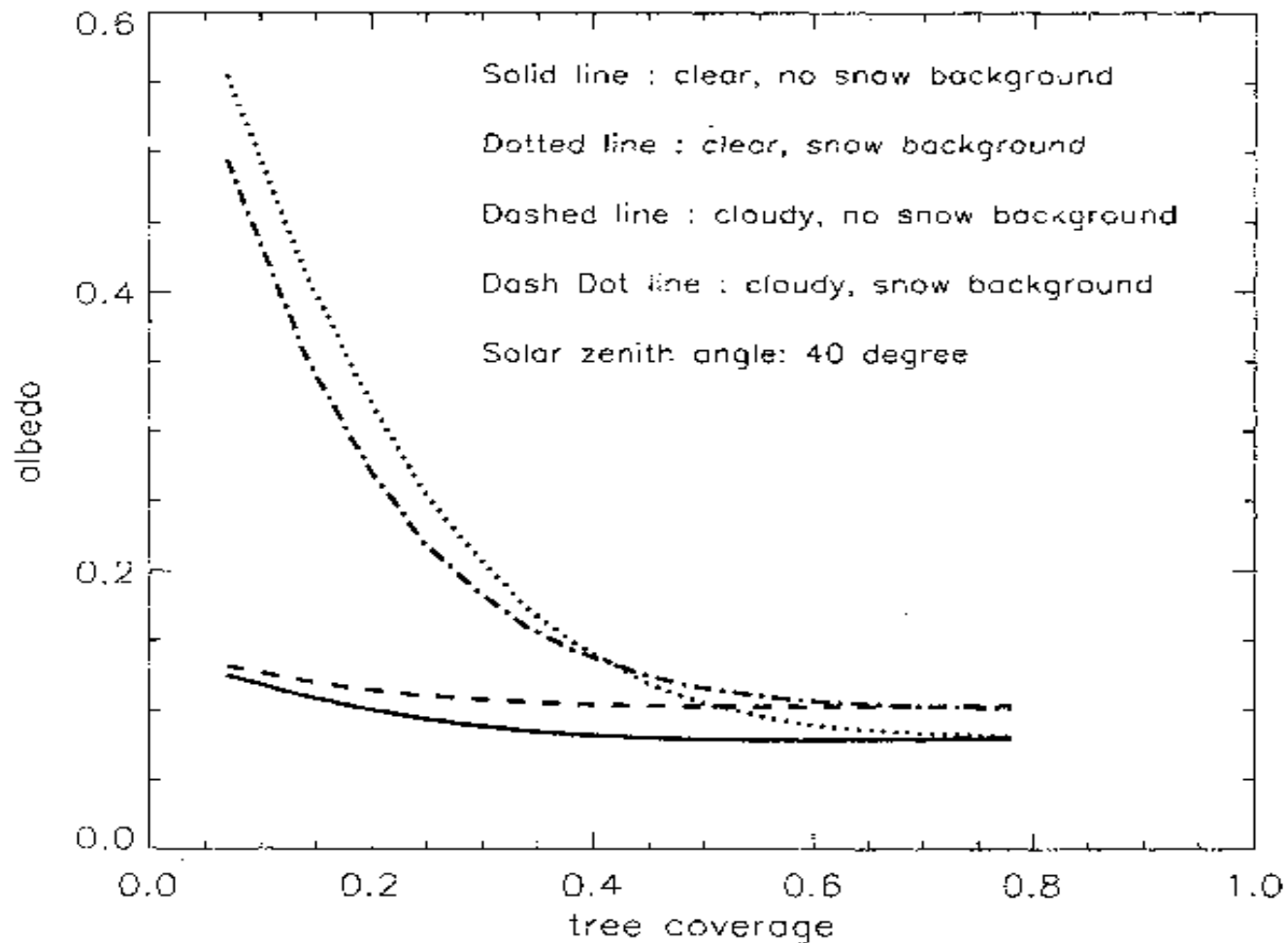
The analytical clumped two-stream (ACTS) canopy radiative transfer scheme for Dynamic Global Vegetation Models - Ent



Applications of the GORT Model

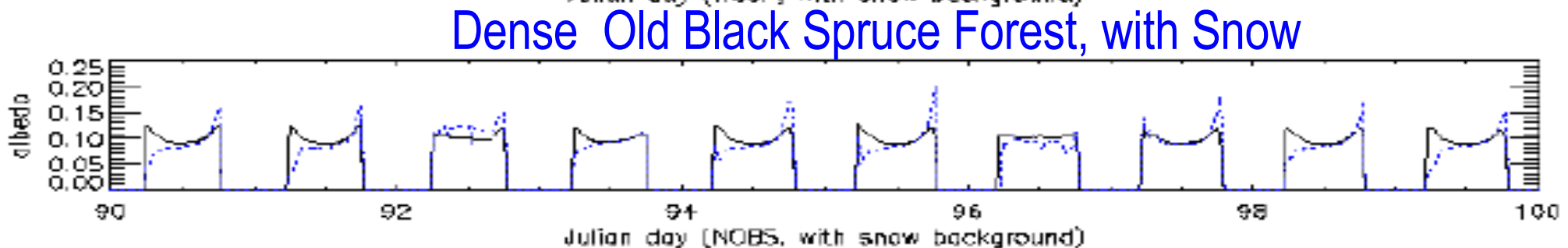
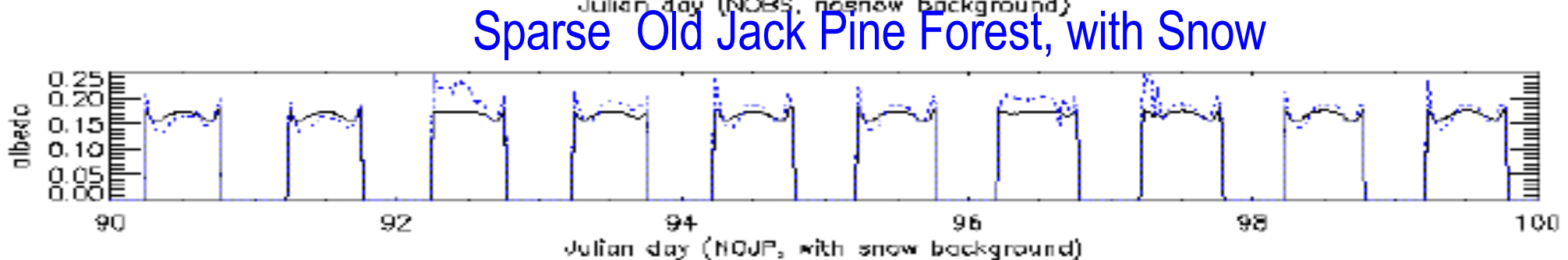
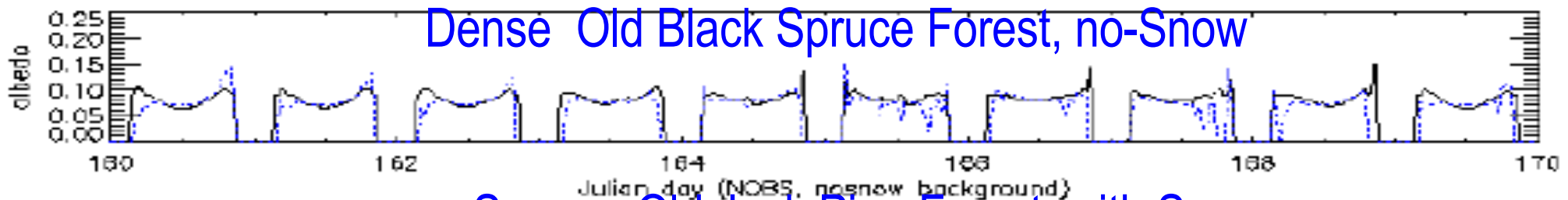
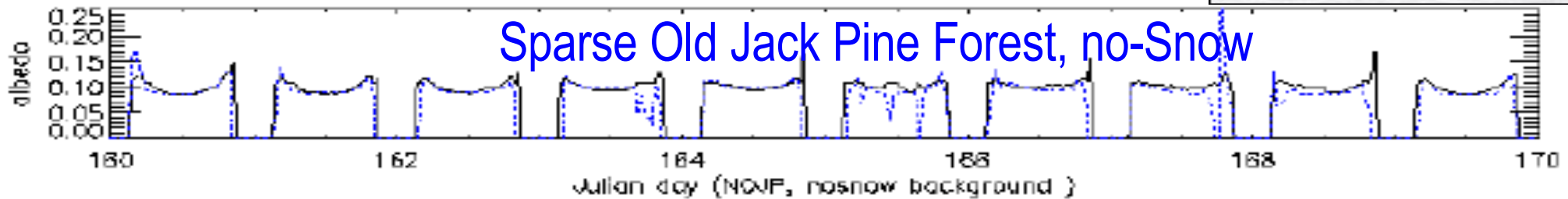
- Remote sensing applications
 - BRDF (Li et al. 1995; Ni et al. 1999a+b; Ni and Li 2000; Ni and Jupp 2000)
 - Lidar (Ni-Meister et al., 2001, 2018; Yang et al. 2011, Lee et al. 2011; Ni-Meister et al. 2008)
 - Topography effect on lidar returns
 - Radar backscattering (working in progress)
- Vegetation dynamic modeling
 - APAR (Ni-Meister et al., 2010; Yang et al., 2010)
 - Surface albedo (Ni and Woodcock, 2000, two in progress)
- Hydrology application
 - Snowmelt application (Ni and Gao, 2011)

Vegetation structure affects surface albedo



Change of surface albedo with vegetation cover
(Ni and Woodcock, 2000)

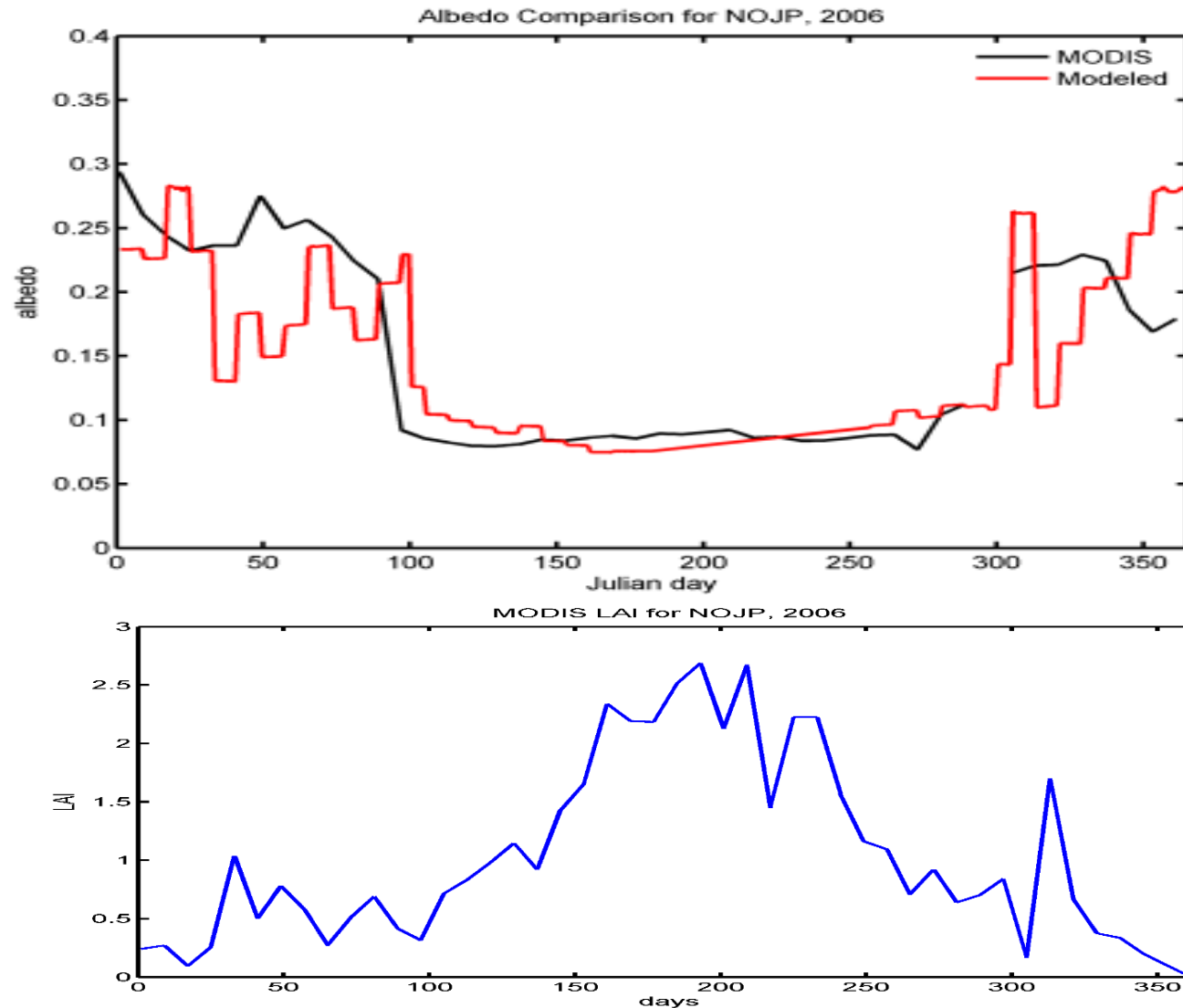
Surface Albedo Over Boreal Forests



BLUE: Measurements BLK: GORT

Ni and Woodcock, 2000

Comparison of Modeled Seasonal Change of Surface Albedo in Boreal Forest with MODIS Measurements



Comparison of measured (black) and ACTS modeled (red) noon surface albedo in 2006 over the old jack pine (NOJP) forest stands in the northern study area of BOREAS.

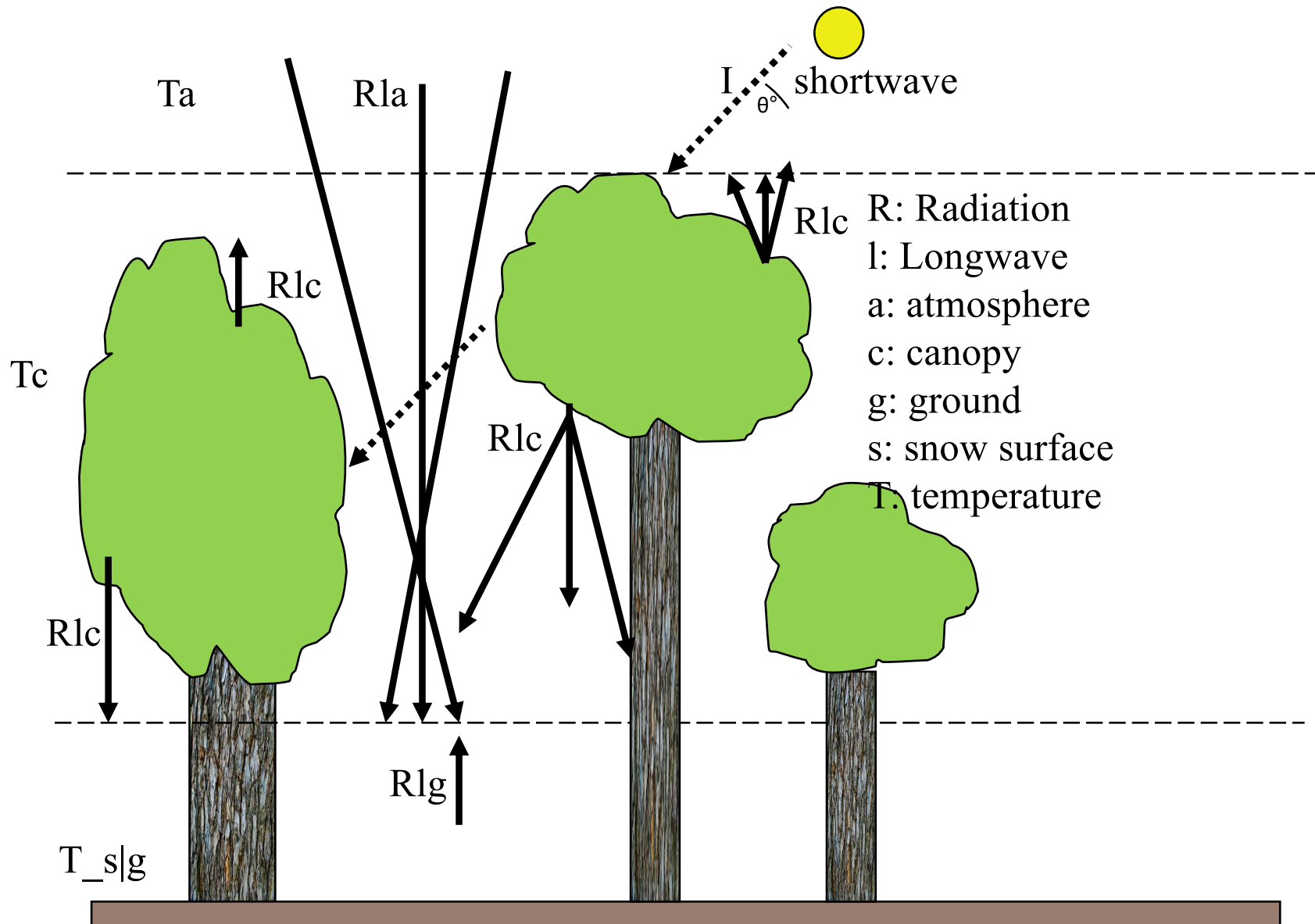
Conclusion – Vegetation on Albedo

- Vegetation structure has stronger effect total albedo in winter than in summer
 - Vegetation cover/density
 - Solar zenith difference
 - Geographic difference
 - Tree height – shading effect
 - Solar zenith difference
 - Geographic difference
 - Species – deciduous vs conifer
- The power of lidar and albedo measurements
- Question - How long snow stays on trees?

Impact of Vegetation Structure on SWE and Snowmelt through Modifying Incoming Radiation at Snow Surface

- Compared to homogeneous vegetation, clumped / discontinuous vegetation structure leads to
 - increased incoming shortwave radiation at snow surface, depending on :
 - Vegetation cover/clumping
 - Solar zenith angles (higher SZN, closer to homogeneous canopy)
 - Dominant role in mid-latitude
 - decreased incoming longwave radiation at snow surface
 - Depending on vegetation cover/clumping
 - Independent on solar zenith angles
 - Stronger role in high-latitude

Impact of Clumped Vegetation on Incident Shortwave and Longwave Radiation



Snowmelt response to changes in forest structure after MPB in the headwaters of the Colorado River by Pugh and Small (2011)

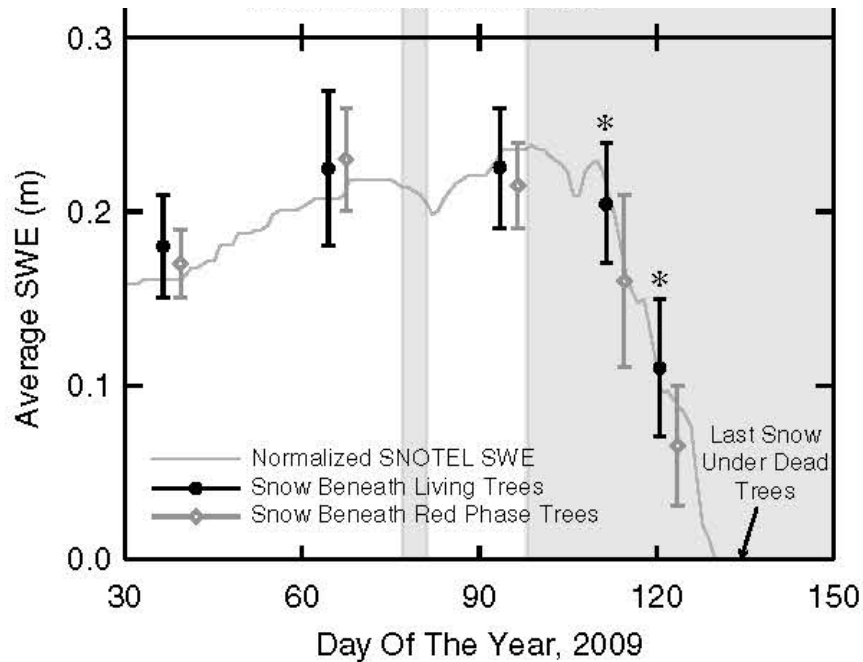


Figure 5. Temperature and SWE records for Winter 2009. Snow beneath living and red phase dead stands became isothermal on the same date. The included 2009 SNOTEL SWE record is normalized to the 25 year (1984–2008) average maximum SWE. Error bars represent 1 SD. *Indicates significant differences at $p < 0.05$.

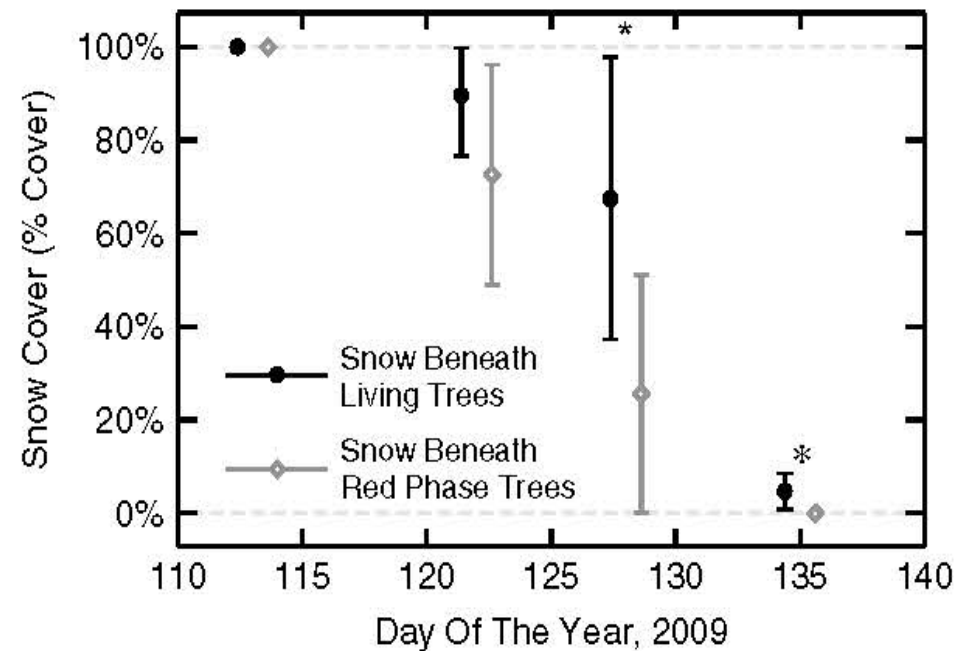
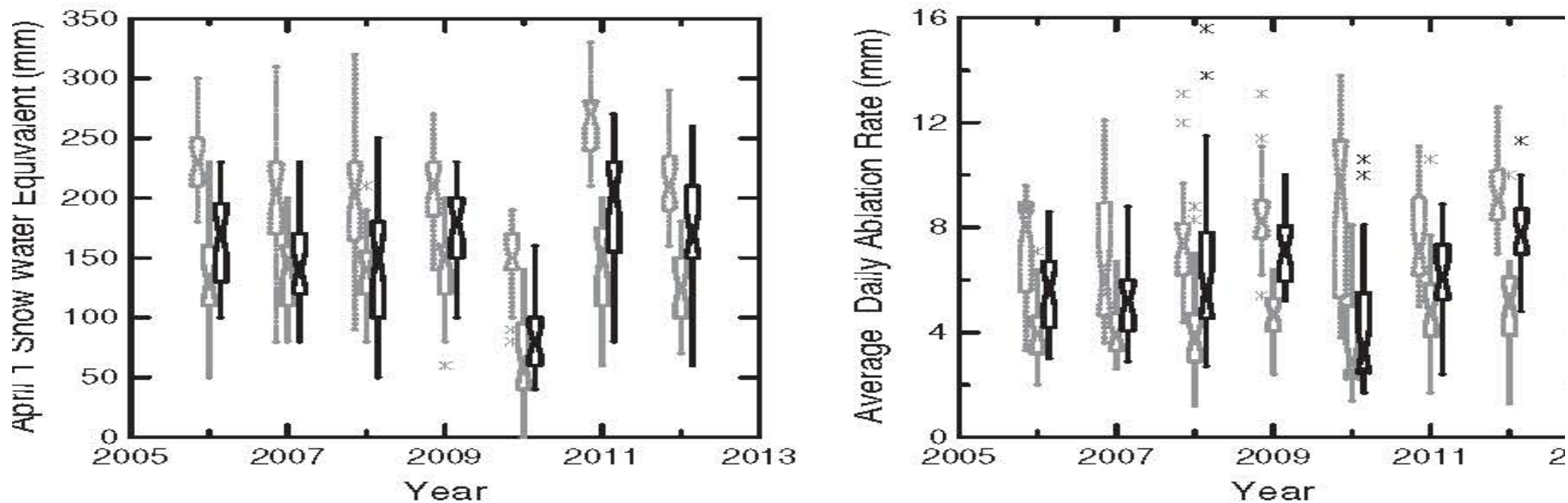


Figure 6. Percent snow cover between 20 April (DOY 110) and 20 May (DOY 140), 2009. Error bars represent 1 SD. *Indicates significant differences at $p < 0.05$.

Snow accumulation in red phase stands was 15% higher than in paired living stands. Snow in red phase stands melted more rapidly than in living stands, likely as a result of increased canopy shortwave transmission.

Snow accumulation and ablation response to changes in forest structure after attacked by Mountain pine beetle in south-central British Columbia by Winker et al. (2012)



water equivalent and average ablation rates in the clearcut (CC, dotted grey), mature mixed (M, solid grey), and young pine (YP, black) stands

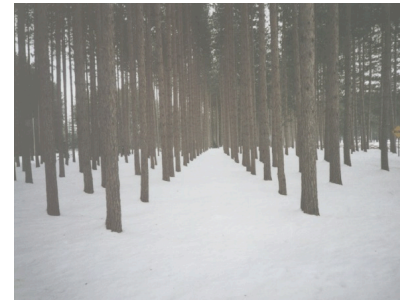
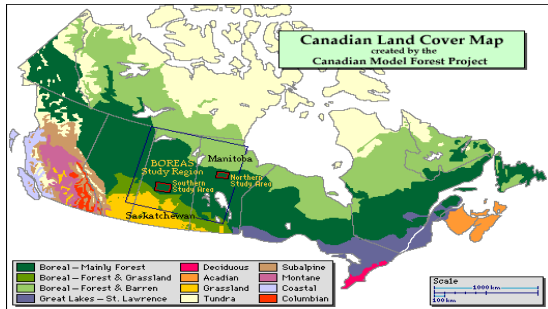
2006-2012 measurements show fastest snow melt in the mature mixed (grey), then young pine stand (black) and then the clear cut site (dotted grey).

Contradict to the claim before: In most cases, the short-wave energy reduction is the dominant effect, resulting in a slower melting rate compared to open areas (Sicart et al. 2004)

Variable Infiltration Capacity (VIC) Macroscale Hydrologic Model



Snowmelt Prediction



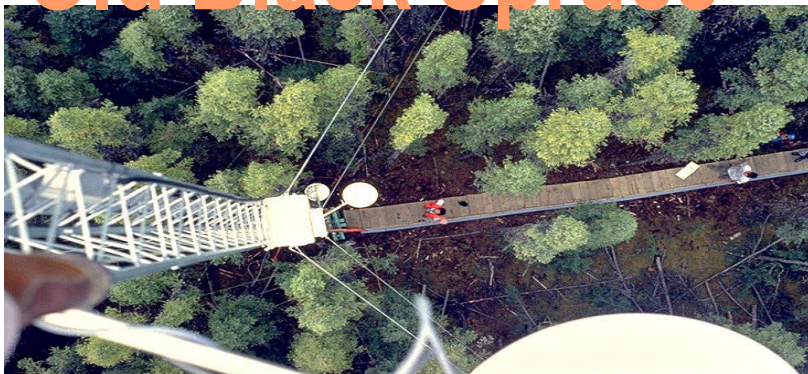
Old Aspen



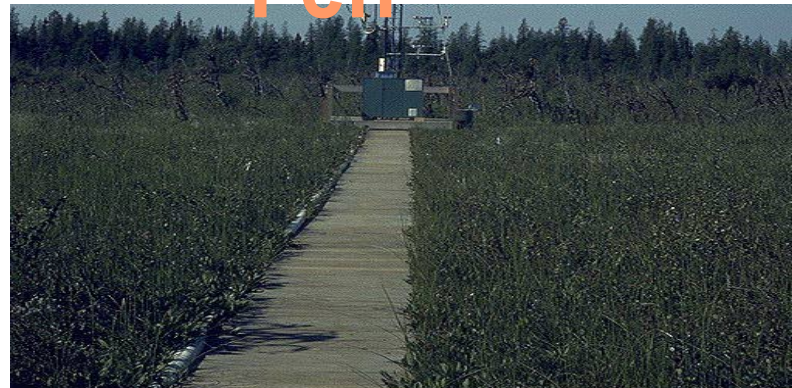
Old Black Spruce



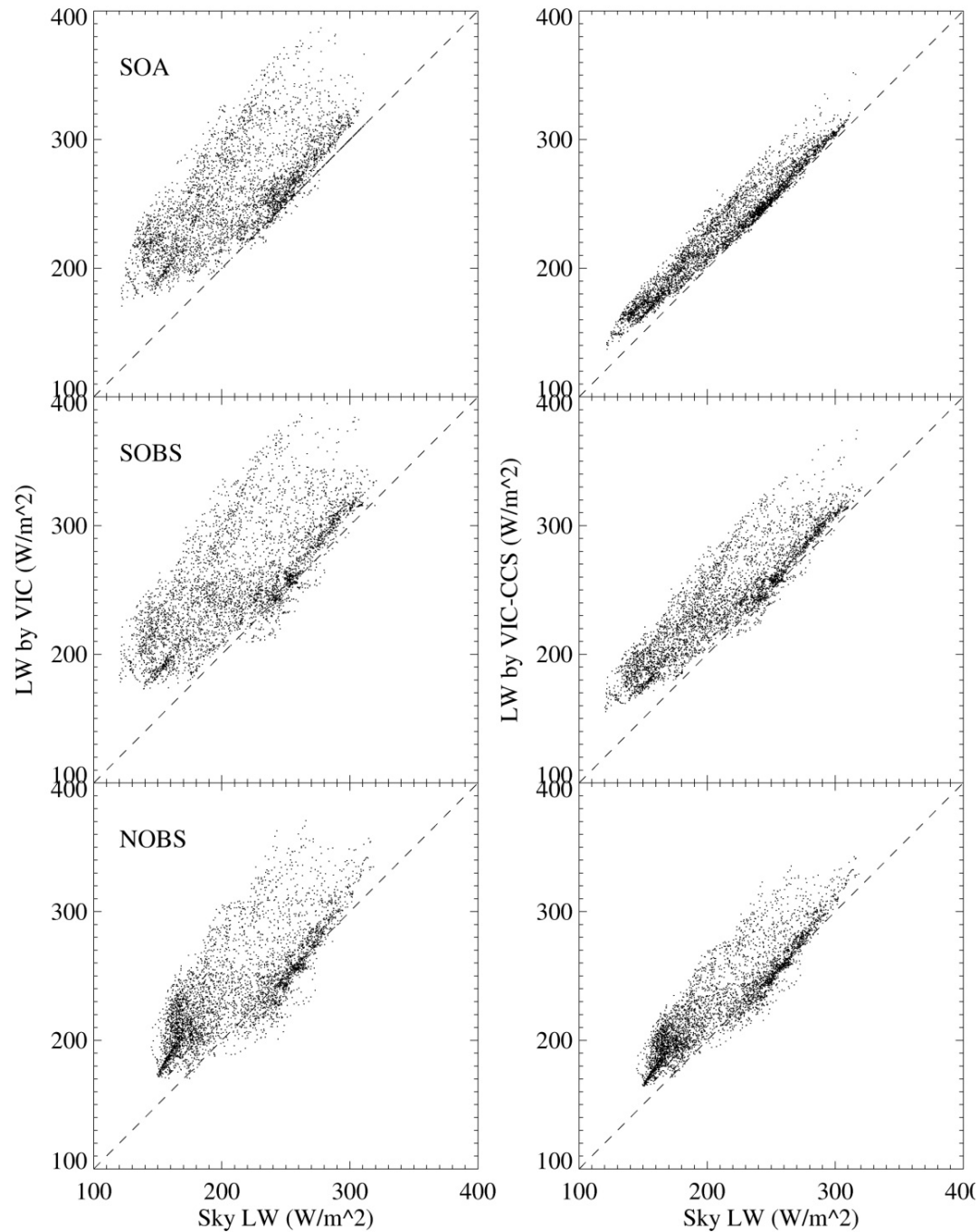
Old Black Spruce



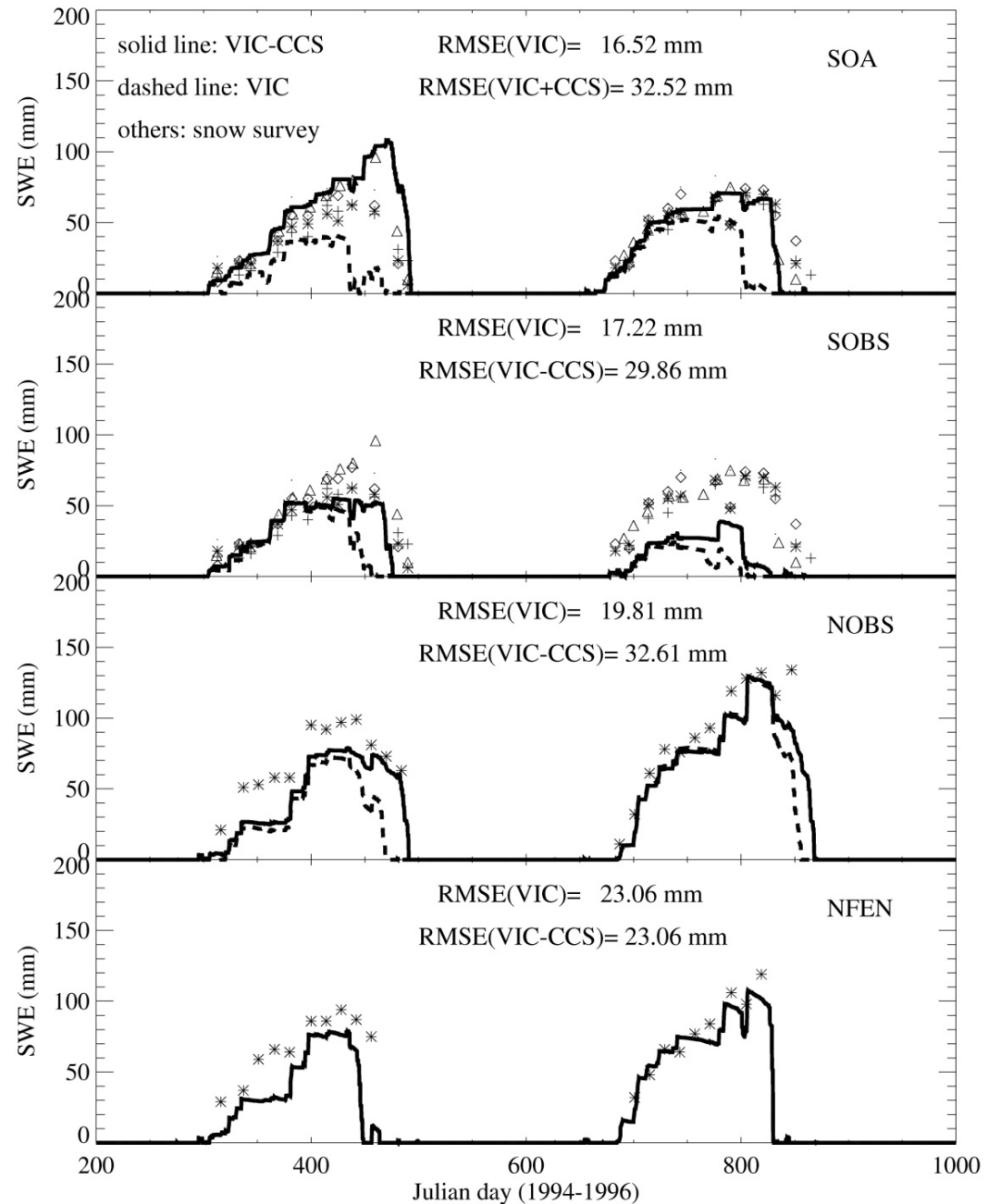
Fen



Incoming Longwave Radiation at the Snow Surface



Snowmelt Prediction



Conclusions – Vegetation Effect on SWE

- **Compared to homogeneous/dense vegetation, clumped vegetation structure results in**
 - **Increased incoming shortwave radiation at snow surface**
 - **Decreased incoming longwave radiation at snow surface**
- **Our test and previous measurements confirm that**
 - **The first factor is stronger in mid-latitudes**
 - **The second factor is also strong in high latitudes**

Implications for SnowEx –ABOVE

- SWE and surface albedo vary with vegetation density, height and species
- The impact of vegetation structure on SWE and albedo vary with geographic regions (mid-latitude vs high latitude)
-
- Full waveform lidar and optical measurements with measurements of vegetation structure, snow depth/SWE and snow albedo can be a very powerful tool to assess impact of vegetation structure on SWE and albedo